The Technical and Economical Analysis of the Air-conditioning System Usage in Residential Buildings in Beijing[1]

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Abstract: In this paper, we show that the air-conditioning usage in residential buildings in Beijing grows rapidly in relation to the development of civil construction. More and more people are not satisfied with the current style of only using split air-conditioning units in residential buildings, and are using the central air-conditioning system in residential buildings. To determine the best air conditioning mode, a residential tower building with 22 layers was chosen for analysis. The advantages and disadvantages of the central air-conditioning system and the residential multi-unit air-conditioning equipment system and the LiBr absorption chiller were compared based on calculating the first-cost and the annual cost (according to providing cooling 90 days annually). The predicted results show the economical feasibility of using the refrigerating units in air-conditioning systems in Beijing region, and point out the developing directions for the future.

Key words： model chosen technical analysis economical analysis

[1]

1. INTRODUCTION

At present, most high commercial buildings use central air-conditioning system, whereas it is used less in the residential buildings. However, the residents not only concern with the central air-conditioning system, but also are interested with the multi-units air-conditioning equipment such as split system air-condition. It is considered that the first-cost and running cost of both cooling and heating sources are the main cost in the air-conditioning project of high buildings in the urban area. Therefore, to achieve the good economic benefit, consuming energy properly and protecting the environment, it is important and necessary to choose the reasonable cooling and heating sources which is based on correctly technical and economical analysis.

In this paper, a residential tower-building with 22 layers was chosen as analyzing target, which has the room of 80 - 120 square meters area and 2.9 meters tall for each room. The design model of the central air-conditioning system and that of the multi-units air-conditioning equipment are compared based on technical and economical analysis. Finally, the performance differences of them using in the residential area are found, which is valuable in practice of choosing air-conditioning equipments.

2. TECHNICAL ANALYSIS

2.1 Characteristics of Central Air-conditioning Powered by Electricity [1],[2]

It is known that the electric air-conditioning has many merits such as clean, safety, high COP, longevity of service, low price and maintenance easily. But it also has weak aspects, for example, its power consumption is higher, which has became the main hidden trouble of electric network safety; furthermore, this kind of air-conditioning system has more components, loud noise, and can be abraded easily. Several major factors must be considered when choosing the system as cooling source: the chilling capacity adjusted, *COP* value, stability of running, service life, maintenance, price, and so on. There are 3 kinds of common water chilling units, which are the centrifugal compressor chiller，the

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reciprocating compressor chiller and the rotary screw compressor chiller, The common characteristics of them are mature in technique, have high *COP* value. The COP of reciprocating compressor chiller is about 3.5, rotary screw compressor chiller about 4, centrifugal compressor chiller up 4.5). The differences of their performances are shown in the Tab. 1, which approves that the screw unit and centrifugal compressor chiller are better for using.

Tab. 1 The performance of different cooling source[1]

Comparing index	Air-conditioning units		
COP （high~low）	Centrifugal compressor chiller	Rotary screw compressor chiller	Reciprocating compressor chiller
Energy adjustable capacity (strong ~ weak)	Rotary screw compressor chiller	Centrifugal compressor chiller	Reciprocating compressor chiller
Price （low ~high）	Rotary screw compressor chiller	Centrifugal compressor chiller	Reciprocating compressor chiller unit
Size (small ~large)	Reciprocating compressor chiller	Rotary screw compressor chiller	Centrifugal compressor chiller

2.2 Characteristics of DFLBAC Used in Air Conditioning System [3]

The Direct Fired Lithium Bromide Absorption Chiller (DFLBAC) is a model developed from the Lithium Bromide absorption-refrigerating machine using steam. It uses heat of high temperature fume that comes from the burning of nature gas, fuel or LNG. The DFLBAC works on the principle of absorption refrigeration circulation to produce the cooling or hot water, and affords the cooling load in summer and heating load in winter. The characteristics of the machine are as follows：

The LBACCNG is operating at minus pressure and high vacuum, having no dangerous of explosion; have no yawp parts besides canned motor pump. The noise of the machine is very low, maintenance work is simple, and the refrigerating capability of the unit is steady. It can operate steadily at the condition working state: calefaction steam pressure of 0.2~0.8 Mpas, the temperature 5~15□ of chilled water ; The adjustable range of the chilling capability for the machine is from 20% to 100%.

2.3 Residential Multi-units Air-conditioning Equipment [4] [5] [6]

Residential multi-units air-conditioning equipment is mainly used for the residential buildings for cooling and heating. The refrigerating output is between 7kW～80kW.

There are 3 kinds of residential multi-units air-conditioning equipment, which are the air-to-air package heat pump unit, the forced-air unit and the refrigerant fluid unit.

2.4 Air-to-air Package Heat Pump Unit

Air-to-air package heat pump unit chooses air as the cooling source, fan-coil as the terminal diffuser, the cooling load and heating load are transferred by the medium of chilling and hot water. It is mounted and operated easily. Its characteristics are shown as follows:

- Merits：

1) Noise is low，which is 30—40dB(A) when it runs at low speed；

2) The speed of fan-coil unit's fan can be adjusted at the stage of high, medium or low speed; the water pumps, sensors and adjuster can control the temperature of room automatically. The machine would stop when there is no anybody in the room, so it could run economically.

3) The small size of the fan coil can be mounted easily.

4) It is easy to increase the number of fan coil units when the construction area is enlarged.

- Demerits：

1) It may contradict with building layout sometimes.

2) The workload of maintenance and management is large when there are more units.

3) The problem of supplying fresh air is more different ，and the air quality of the room

would become poor.

There are two sorts of air-to-air package heat pump unit the unit with unvarying rotating speed unit and the unit with varying frequency. The unit with varying frequency is attracting more and more people because it can adapt the change of heat load better reasonably. Its refrigerating rate is fast; its temperature of chilling water falls small when defrosting.

2.5 The Forced-Air System

The forced-air system is composed of the outdoor portion of air-to-air heat pump unit, plenum, duct system and registers. It is suitable for the villa and the high raise buildings with more 3 meters height of each floor. Its characteristics are shown as follows:

- Merits：

1) Its first-cost is less and indoor units occupy smaller floor area

2) The management-cost of the duct system is less than that of the water system.

3) It has high COP value and can supply enough fresh air to the room conditioned.

- Demerits：

1) It is hard to adjust the rate of air supplied into rooms conditioned; the air ducts occupy a lot of space; it is also not easy to filtrate and dehumidify the air

3) The system's running cost is high; noise is loud; energy-saving worse.

4) The temperature of room is unstable when defrosting

- Difficulty：

Most of domestic people can afford the cost of unit but cannot pay the high running cost, because the low-level of consumption in China.

2.6 The Refrigerant Fluid Unit

The refrigerant fluid unit covers one or several outdoor portions and indoor portions. The unit is composed of refrigerating compressor, indoor and outdoor heat exchangers and throttle device, and the refrigerant inside system tubes evaporates and condenses directly. This kind of unit usually adopts varying-frequency technology, its characteristics are shown as follows：

- Merits：

1) It is good at energy-saving and its running cost is low (energy-saving between 35～45% than that of the traditional water chiller during running).

2) Managing easily, advanced controlling means, and the indoor temperature can be controlled within±0.5□.

3) It is free to design and mount, and its noise is lower;

4) It can save the ceiling area, and condensation water will not drip;

5) Work temperature range is wide, (the most low temperature in winter is -15□) , so it will not frostbite in winter.

6) There is no need to establish the chilling and hot water systems, and save the area of machinery room.

7) Both the reliability and energy efficiency ratio are relative high.

8) The refrigerating capacity follows the room load well, and with excellent adjusting characteristic within the varying frequency range.

- Demerits：

1) The problem of supplying fresh air is different, and the air quality is not good.

2) The first-cost is high and the maintenance hard.

3. ECONOMICAL ANALYSIS

To make sure whether it is suitable to use these units in the residential buildings, a project is set for comparison.

3.1. Summary of the Project

The project is a tower-building with 22 floors in Beijing, air-conditioning area is 27000m^2, and each room area is 80～120 ㎡，the height of each floor is 2.93 meters. The maximum load in day is 2295kW, and the maximum load at night is 1767kW。

3.2. Options Chosen

Tab. 2 Options chosen

Option One	Electrical air-conditioning (rotary screw compressor chiller)
Option Two	DFLBAC
Option Three	Residential multi-units

	air-conditioning equipment （Refrigerant Fluid Unit）	
	Automatically controlling system	11.96
	Electrical system	66.98

3.3. Equipment Chosen

Tab. 3 System collocated of the central air-conditioning with rotary screw compressor chiller (×10^4 Yuan)

Option one		
Equipment names	Technique parameters	Price
Rotary screw compressor chiller	C300A	104.0
	C350A	
Chilling water pump	100DL100-20×2	7.90
Cooling water pump	100DL100-20×2	3.90
	150DL150-20×2	3.40
Cooling tower	333m^3/h, 11kw	21.17
Air conditioning unit	BFC36	45.00
Air duct		90.87
Wind register, air plenum(200×200，300×300)		28.80
Chilling water pipe		15.83
Cooling water pipe		16.97
Automatically controlling system		11.31
Electrical system		63.34

Both the central air-conditioning and the residential multi-units air-conditioning equipment choose the units that is well known in the world.（The detail equipments are shown from the Tab.3 to Tab. 5.

Tab.4System collocated of central air-conditioning with LBACNG(×10^4 Yuan)

Option two		
Equipment name	Technique parameters	Price
DFLBAC	C-050	138.00
	C-018	
Chilling water pump	100DL100-20×2	2.62
	150DL150-20×2	5.10
Cooling water pump	150DL150-20×2	6.80
	150DL160-20×2	4.22
Cooling tower	240 m^3/h，7.5kw	9.00
	550 m^3/h， 22kw	13.39
Air conditioning unit	BFC36	45.00
Air duct		90.87
Wind register, air plenum (200×200，300×300)		28.80
Chilling water pipe		16.74
Cooling water pipe		17.94

Tab. 5 The first-cost of the residential multi-units air-conditioning equipment (×10^4 Yuan)

Name		Equipment cost
Indoor units	B-R20P/L	104.77
	B-R25P/L	32.03
	B-R35P/L	34.71
	B-R50P/L	42.16
Outdoor units	B-R80W/A	42.87
	B-R100W/A	186.17
	B-R120W/A	141.88
	B-R140W/A	5.83

Tab. 6 The first-cost of different Options (×10^4 Yuan)

	Option one	Option two	Option three
First-cost	412.49	457.42	590.42

3.11 The Count of Annual Cost

The annual cost of air-conditioning contains two parts: the permanent cost, which contains depreciation expense, and so on; variable expense, which includes water, electric and gas consumption during the running process; labor cost, maintenance and repair cost, and so on.

3.12 The Count of Each Option's Permanent Cost, Labor Cost, Maintenance and Repair Cost

The permanent cost is calculated as bellow:

The first-cost of equipment proportions into the cost of each year, based on the annual interest rate and the service life of equipments

The service life of main equipments of units are 15 years, the annual interest rate is 5%, according to the formula bellow ：

$$P = O \times i \times (1+i)^n / [(1+i)^n - 1]$$

Where,

P---- permanent cost； O --- first-cost；

i ---- annual interest rate； n --- service life；

The results are shown in the Tab. 7.

3.7 Maintenance and Repairing Costs

The cost of maintenance and repairing is equal to the 10% of permanent cost. The results are shown in the Tab. 7.

3.8 Labor Cost

Option one： 2 labors， 3000yuan/Month·People；

Option two： 2 labors， 3000yuan/Month·People；

Option three：None

The results are shown in the Tab. 7.

3.9 The Running Cost of Each Option

●According to the code of energy and electrical in Beijing, the residential electrical price is 0.48 Yuan/kW·h.

●The supply cooling period of Option One in Beijing is 90 days annually , which contains 7days running at 100% load, 42days running at 80% load, 41days running at 60% load, and the total cooling coefficient is 19.79. Above all, the full load running time of Option One is calculated as bellow：19.79×(7+42×0.8+41×0.6)＝1290 hour

●According to reliable investigation, the cooling period of Option Three is set as 738 hours running at full load.

The calculation result is shown in the Tab. 7

The final count is shown in the Tab. 8.

Tab. 7 The annual cost of each Option （×10^4 Yuan）

	Option one	Option two	Option three
Permanent Cost	39.74	44.07	56.88
Maintenance and Repair Cost	3.97	4.41	5.69
Labor cost	7.20	7.20	0
Running cost	57.26	70.73	28.78 ▲ 50.32 •
Annual cost	108.17	126.407	91.35▲ 112.89•

Note: ▲--- running 738 hours annually

•--- running 1290 hours annually

Tab. 8 The summary sheet of the first-cost and the annual cost for each Option （×10^4 Yuan）

	Option one	Option two	Option three
First-cost	412.49	457.42	590.42
First-cost ratio	100%	111%	143%
Annual cost	108.17	126.41	91.35▲ 112.89•
Annual cost ratio	100%	117%	84%▲ 104%•

4. ECONOMICAL COMPARING AND ANALYSING

4.1. The Comparison of the First-Cost for Each Option (Fig 1.)

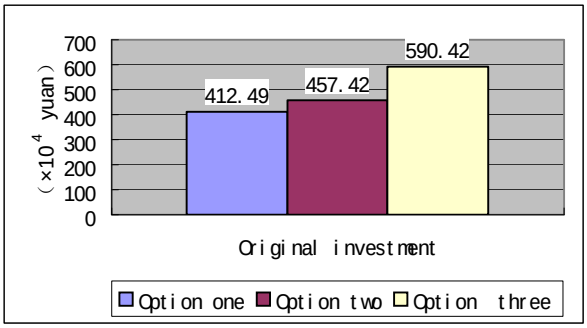

Fig. 1 The comparison of first cost

Analysis：

1) According to Fig1. The results of first-cost comparison is

Option One < Option Two< Option Three.

2) According to Tab. 8. Option Two's first-cost is 11% higher than that of Option One. Option Three's first-cost is 43% higher than that of Option One.

4.2. The Comparison of Annual Cost for Each Option (Fig 2.)

Analysis：

According to Fig2. Option One has the lowest annual cost than that of other two options at the condition of 738 running hours.

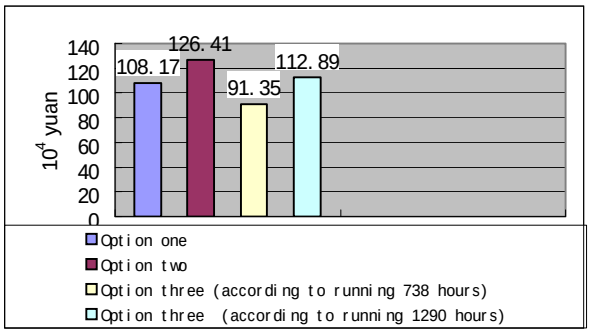

Fig. 2 The comparison of annual cost

5. CONCLUSIONS

1 From the analysis of first-cost, the residential multi-units air-conditioning equipment is higher than that of DFLBAC and Rotary screw compressor chiller.

2 From the analysis of annual cost, the cost of LBACNG is higher than that of the electric air-conditioning, because the civil electric price is low, and the natural gas price is higher in Beijing. Although using the LBACNG can compensate some of electricity shortage, the high annual cost make it hard to popularize. So compared with the rotary screw compressor chiller, it is not suitable for the residential buildings.

Two running time periods were chosen as the residential multi-units air-conditioning equipment during the comparison because different people can conveniently regulate the residential multi-units air-conditioning equipment at any time and any room. As the civil consumption level is low, most users are interesting in " reducing running time as much as possible ", so the annual running time of the residential multi-units air-conditioning equipment is less than 800 hours, that's why the annual cost of Option Three is less than that of Option One. If the running time is set as 1290 hours, the annual cost of Option Three is 5% more than the Option One.

In short, the central air-conditioning (rotary screw compressor chiller) is the first choice as the air-conditioning equipment using in the residential high tower buildings in Beijing. To compensate the electricity shortage, the LBACNG could also be used as a choice. The residential multi-units air-conditioning equipment still belongs to high-level consumption, which is not suitable for the commonalty residential high-rise buildings.

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